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(56) Documents Cited

GB 2210087 A  
US 5706896 A

EP 0773345 A1  
US 5531270 A

(58) Field of Search

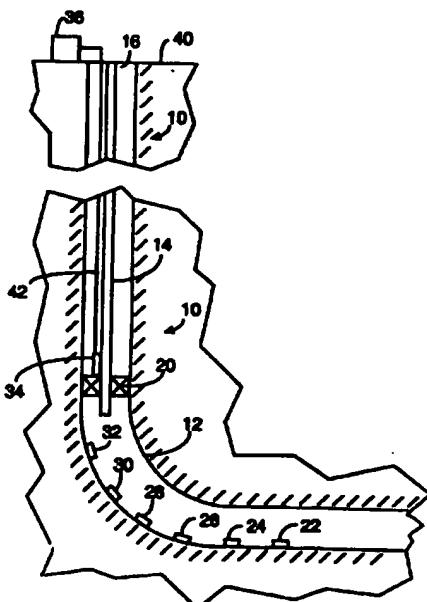
UK CL (Edition P ) E1F FHK FHU FLM  
INT CL<sup>6</sup> E21B 47/12 47/14 47/16 47/18  
Online: WPI

(54) Abstract Title

Downhole data acquisition apparatus

(57) A data acquisition apparatus for use in a wellbore comprises an array of sensing devices (22, 24, 26, 28, 30, 32) attached to the inner surface of casing (12) and a master unit (34) positioned towards the downhole end of a wellbore (10). The master unit (34) is connected to a receiving and processing unit (36) on surface (40) by an electrically conductive cable (42). Each sensing device comprises a first transceiver, a processing unit, a second transceiver, a power supply unit and sensors. The sensors detect downhole parameters such as pressure, temperature, flow rate and resistivity. Signals from a sensor are processed in a sensing device and passed on to a sensing device further down the array. Here these signals are combined with the signals from the sensors in another sensing device and this combined signal sent onto further sensing units in a "bucket brigade" mode. These signals are subsequently passed along the array until they are eventually passed to the master unit (34) for transmission to the surface. Preferably the sensing units communicate using wireless telemetry such as acoustic waves.

FIG. 1



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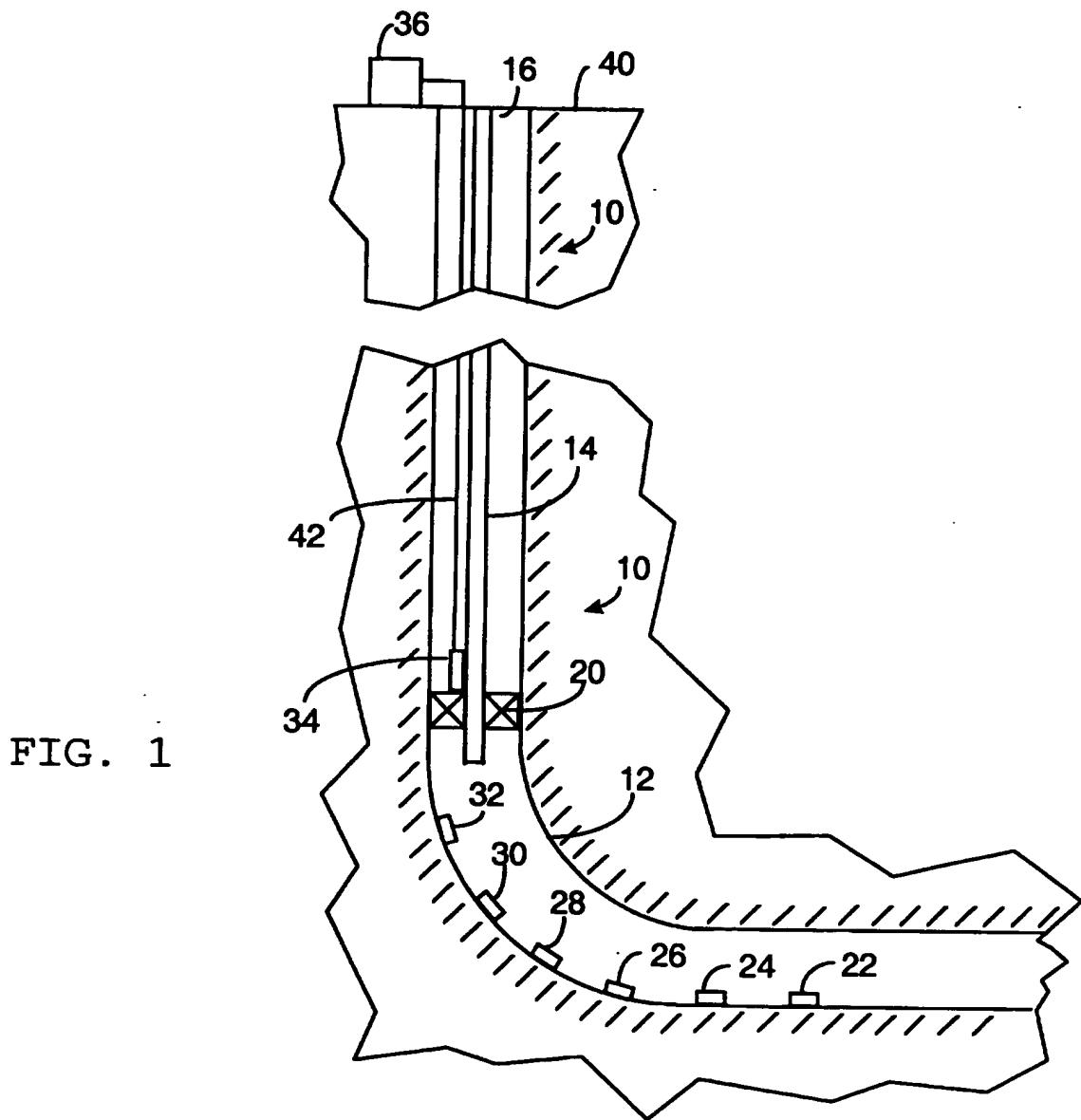


FIG. 1

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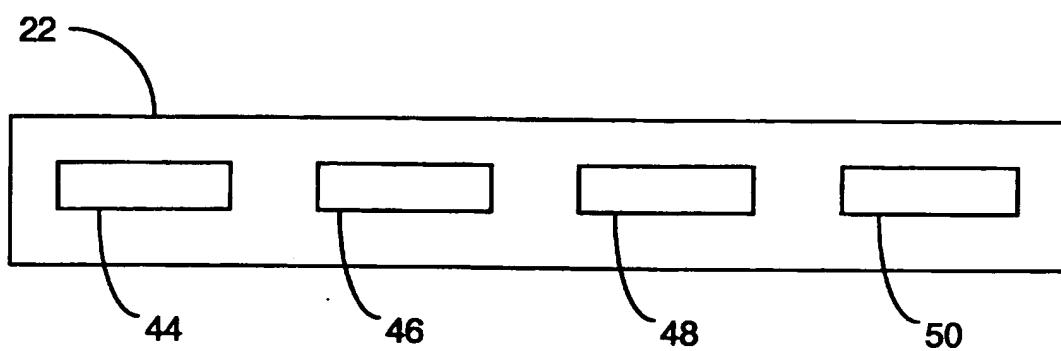


FIG. 2

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### Data Acquisition Apparatus

This invention relates to data acquisition apparatus for use in  
5 a wellbore and a method of acquiring signals down a wellbore.

#### BACKGROUND OF THE INVENTION

10 Data acquisition apparatus, including sensors, is often provided in a wellbore to monitor the movement of fluid within a fluid producing reservoir or movement of fluid within the wellbore itself. In a wellbore with casing and tubing in place, sensors are typically placed behind the tubing, so as to be in an  
15 annulus between tubing and casing, and the sensors are connected to the surface by a cable positioned in the annulus. The cable provides both power and telemetry to the sensors. It has been attempted to deploy the sensors behind casing, connecting the sensors to the surface by a cable which passes through the  
20 cement holding the casing in contact with the outer wall of the wellbore. However problems have arisen with such techniques due to the difficulties of protecting the cable during installation, and ensuring that the quality of the cement is not affected by the presence of the cable, as otherwise zonal isolation cannot  
25 be maintained.

It has been proposed to avoid such problems by providing a wireless telemetry link from downhole to surface. However problems also arise with this approach in relation to signal  
30 attenuation and transmission range.

#### SUMMARY OF THE INVENTION

According to one aspect of the present invention, there is  
35 provided a data acquisition apparatus for use in a wellbore, comprising a receiving means attached to an elongate electrical connector for conveying signals from downhole to surface, and a

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plurality of sensing devices adapted to be positioned downhole in spaced apart positions remote from the receiving means, so as to form an array of sensing devices.

5 Typically the electrical elongate connector is a cable attached to a surface processing unit which can both receive and transmit signals along the connector.

Preferably the receiving means includes a transmitter so as to  
10 allow two-way travel of signals within the wellbore. Thus both  
uphole and downhole transmission of signals is enabled, allowing  
acquired data to be forwarded uphole and command signals from  
the surface to be sent downhole to the sensing devices via the  
receiving means.

15 The present invention is particularly of use when acquiring data  
in near-horizontal wells, or horizontal wells, and in such  
situations the receiving means is preferably located within the  
vertical part of the wellbore, with the sensing devices adapted  
20 to be positioned along the near horizontal or horizontal portion  
of the wellbore. The use of a receiving means with an  
electrical connection to surface to carry signals over the  
vertical section of the wellbore substantially reduces the  
number of spaced sensing devices required to transmit the signal  
25 from downhole to surface over the number required for pure  
wireless telemetry along the entire length of the wellbore.

Preferably each sensing device has at least one sensor, a  
transmitter and a receiver. This allows data acquired by one  
30 sensor to be transmitted to a receiver on a neighbouring sensing  
device for transmittal from the neighbouring sensing device to  
the next neighbour, et seq. Data signals thus may be relayed  
along the array of sensing devices until the last sensing device  
in the array transmits all acquired data to the receiving means.

35 Each sensing device may include a plurality of sensors so that  
data relating to different parameters, such as temperature,

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pressure, resistivity, and fluid flow, can be acquired.

Each sensing device may be provided with a processing unit to allow signals received from a sensing device further down the 5 array to be combined with its own signal, so as to produce a combined signal for onward transmission to the next sensing device in the array.

Preferably each sensing device is provided with first and second 10 transceivers, the first transceiver receiving a signal from a first neighbouring sensing device in the array, and the second transceiver transmitting the combined signal to a second neighbouring sensing device in the array.

15 In some arrangements, the sensing devices may be able to move within the wellbore, and to this end may be in the form of robot-like entities.

In other arrangements, the sensing devices may be permanently 20 fixed in position within the wellbore, typically by incorporating the sensing devices into casing, either internally or externally. With such permanent positioning, the sensing devices require a downhole power supply, which may be provided for example by means of batteries. However the power available 25 downhole will be limited compared to that which would be available with a power connection to surface, and therefore the transmission range of the transceivers associated with the sensing devices will be limited as compared with sensing devices which can be powered from the surface. Boosters may be provided 30 between the sensing devices to ensure that each device is within range of its nearest neighbour or preferably sensing devices may be spaced at intervals along the well such that the distance between each sensing device and its nearest neighbour is not greater than the transmission range.

35

Thus at the limit of operation, without boosters, each sensing device is spaced apart from its near neighbour by a distance

equal to the transmission range. Desirably at least two sensing devices are provided within a distance equal to the transmission range. While this increases the number of sensing devices required downhole, it ensures that a failure of one sensing device does not prevent onward transmission along the array. Thus multiple sensing devices may be provided within the distance equal to the transmission range, and as a preferred example four sensing devices may be provided.

10 Typically the spacing between the individual sensing devices may range from 3 metres to 100 metres.

According to another aspect of the invention, there is provided a method of acquiring signals down a wellbore, comprising the steps of placing a plurality of spaced apart sensing devices within a lower part of the wellbore so as to form an array, and transmitting data acquired by each sensing device to a next one in the array by wireless telemetry, so as to relay data along the array.

20 The use of such a relay technique avoids the need for the sensing devices to have a large power output and consequential large power requirement which would be difficult to support where the sensing devices are autonomous and connection to a surface power supply is not desirable or not possible.

The expression "wireless telemetry" is intended to include any form of wireless communication, for example using acoustic transmission or electromagnetic waves.

30 Preferably the method also comprises placing a receiving means attached to an elongate electrical connector within an upper part of the wellbore, and one of the sensing devices of the array transmits data to the receiving means.

35 These and other features of the invention, preferred embodiments and variants thereof, possible applications and advantages will

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become appreciated and understood by those skilled in the art from the detailed description and drawings following below.

5

#### DRAWING

FIG. 1 is a schematic diagram of data acquisition apparatus, including sensing devices, in accordance with the invention when in use; and

10

FIG. 2 shows a schematic diagram of the sensing device.

15

#### DETAILED DESCRIPTION

In Figure 1, a wellbore 10 is shown in cross-section, with casing 12 cemented in position about the diameter of the wellbore 10 and production tubing 14 placed within a channel defined by the casing 12. Annulus 16 is formed between the 20 casing 12 and tubing 14, and is isolated from fluid further down the wellbore 10 by a packer 20. Sensing units 22, 24, 26, 28, 30, 32 are attached to the inner surface of casing 12 along the substantially horizontal part of the wellbore 10 and are spaced apart at discrete intervals so as to form an array. A master 25 unit 34 is positioned towards the downhole end of the vertical section of the wellbore 10, at the tubing shoe, and is situated just above packer 20 within annulus 16. The master unit 34 is connected to a receiving and processing unit 36 on surface 40 by an electrically conductive cable 42.

30

Each sensing unit comprises a first transceiver 44, a processing unit 46, a second transceiver 48 and sensors 50, as shown for sensing unit 22 in Figure 2. The sensors 50 detect various parameters downhole, such as pressure, temperature, flow rate of 35 fluid within the borehole, and resistivity. The transceivers 44, 48 vibrate to produce an acoustic signal for transmission of data and are receptive to acoustic signals in the wellbore to

receive data.

The sensing units 22, 24, 26, 28, 30, 32 are deployed downhole by attaching them to the casing 12. As the wellbore 10 is  
5 drilled deeper, sections of casing 12 are cemented in position and when in the lower horizontal part of the well, some of the joints of casing fed down the hole have a sensing unit attached to them. A number of sensing units are fed down the hole in this way to form the array of units 22, 24, 26, 28, 30, 32 shown  
10 in Figure 1, with no direct connection to the surface 40. The spacing of the units in the array is achieved by interspersing joints of casing having sensing units attached with joints of casing without sensing units. Each sensing unit is autonomous, having its own power supply, such as a battery, and because of  
15 this has a limited transmission range due to the limited power available to each sensing unit from its associated batteries. In the array of sensing units spaced regularly along the horizontal portion of the well, the distance between each sensing unit and its nearest neighbour is within the  
20 transmission range of the wireless telemetry used by the transceivers 44, 48 to communicate between the units. The sensing units are spaced 50 metres apart, with the sensing unit 32 closest to the heel of the well being within transmission range of master unit 34.

25

After the wellbore has been lined with casing 12, and the sensing units 22, 24, 26, 28, 30, 32 are positioned, the master unit 34 is attached to the outside of the tubing 14 and cable 42. The production tubing 14 and packer 20 are urged downhole  
30 from surface and as the tubing 14 passes further downhole, the master unit 34 and cable 42 follow until the master unit 34 is in the required downhole position. Cable 42 provides master unit 34 with both a power supply and direct communication with the surface receiving and processing unit 36. Both the master  
35 unit 34 and the sensing units 22, 24, 26, 28, 30, 32 are permanent and are not intended to be removed once downhole.

The master unit 34 is essentially the same device as the sensing units, although with a hardwired connection to the surface via cable 42.

5

The use of the data acquisition apparatus is as follows:

Data relating to the conditions within the wellbore 10 is acquired in each sensing unit by the sensors 50 and is passed to transceiver 48, which forwards the data signal to processing unit 46.

Processed signals from the processing unit 46 are then passed to transceiver 44 which produces a vibratory signal in response to the processed data, so producing acoustic (sound) waves which travel through the casing 12 and the fluid in the wellbore.

At the sensing unit 22 furthest down the wellbore, at the lower end of the array, the acquired data signal from sensors 50 is simply passed through the processing unit 46 and onwardly transmitted as an acoustic signal to the next receiver in the array by its transceiver 44. The transceiver 48 of the neighbouring unit 24 detects the acoustic signal from the earlier unit 22 and passes the received signal and the locally acquired signal from its own sensors 50 to its processing unit 46 where the received data signal and the locally acquired signal are combined. The combined signal is then passed to transceiver 44 which transmits the combined signal to the next sensing unit 26 in the array. In this way data is relayed along the array in a "bucket brigade" mode, data being acquired by each sensing unit and added to the data acquired by units lower in the array before onward transmission. This continues along the array until the sensing unit 32 highest in the wellbore at the upper end of the array transmits the total combined data from all the sensing units to the master unit 34, by acoustic transmission through the casing 12 and the tubing 14.

In this way information from the sensor units where the master unit 34 is outside their transmission range, can still be forwarded to the master unit by relaying the signal along the array. So data is transmitted from the bottom of the well (the toe of the well) to the top of the well (the heel of the well), each sensing unit relaying its own acquired data together with the data acquired by sensing units situated below it to the next higher sensing unit in the array. Transmission protocols for such bucket brigade telemetry are known, for example in the D4 transmission zone seismic acquisition system marketed by Geco-Prakla, where radio transmission is used in such a fashion. The data received by the master unit 34 is transmitted by telemetry along cable 32 to surface 40 for processing by surface unit 36 to identify the individual sensor readings within the combined signal.

Where commands are sent downhole from the surface unit 36, these are sent by telemetry along cable 42 to the master unit 34. The unit 34 then transmits the commands via wireless telemetry to the first sensing unit 32 at the upper end of the array. Transceiver 44 receives the command and passes it to processing unit 46 to be decoded for use in the receiving sensing unit 32 and also for onward transmission down the array to sensing unit 30.

CLAIMS

5 1. A data acquisition apparatus for use in a wellbore, comprising a receiver attached to an elongate electrical connector for conveying signals from downhole to surface, and a plurality of sensing devices adapted to be positioned downhole in spaced apart positions remote from the receiver, so as to  
10 form an array of sensing devices.

2. A data acquisition apparatus according to claim 1, wherein the receiving means includes a transmitter so as to allow two-way travel of signals within the wellbore.  
15

3. A data acquisition according to claim 1 or claim 2, wherein the receiving means is located within the vertical part of the wellbore, with the sensing devices adapted to be positioned along the near horizontal or horizontal portion of the wellbore.  
20

4. A data acquisition apparatus according to claim 1, 2 or 3, wherein each sensing device has at least one sensor, a transmitter and a receiver.  
25

5. A data acquisition apparatus according to any of claims 1 to 4, wherein each sensing device includes a plurality of sensors.

6. A data acquisition apparatus according to any of the preceding claims, wherein each sensing device is provided with a  
30 processing unit to allow signals received from a sensing device further down the array to be combined with its own signal, and so as to produce a combined signal for onward transmission to the next sensing device in the array.

35 7. A data acquisition apparatus according to any of the preceding claims, wherein each sensing device is provided with first and second transceivers, the first transceiver to receive

a signal from a first neighbouring sensing device in the array, and the second transceiver to transmit the combined signal to a second neighbouring sensing device in the array.

5 8. A data acquisition apparatus according to any of the preceding claims, wherein the sensing devices are able to move within the wellbore.

10 9. A data acquisition apparatus according to any of claims 1 to 7, wherein the sensing devices are permanently fixed in position within the wellbore.

15 10. A data acquisition apparatus according to any of the preceding claims, wherein the sensing devices are provided with a downhole power supply.

11. A data acquisition apparatus according to claim 10, wherein boosters are provided between the sensing devices to ensure that each device is within transmission range of its nearest 20 neighbour.

12. A data acquisition apparatus according to claim 10, wherein the sensing devices are spaced at intervals along the well, such that the distance between each sensing device and its nearest 25 neighbour is not greater than the transmitter transmission range.

13. A data acquisition apparatus according to claim 12, wherein at least two sensing devices are provided within a distance 30 equal to the transmission range of the transmitter.

14. A data acquisition apparatus according to claim 12, wherein multiple sensing devices are provided within a distance equal to the transmission range.

35 15. A method of acquiring signals down a wellbore, comprising the steps of placing a plurality of spaced apart sensing devices

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within a lower part of the wellbore so as to form an array, and transmitting data acquired by each sensing device to a next one in the array by wireless telemetry, so as to relay data along the array.

5

16. A method of acquiring signals down a wellbore in accordance with claim 15, wherein the method also comprises placing a receiving means attached to an elongate electrical connector within an upper part of the wellbore, and one of the sensing  
10 devices of the array transmits data to the receiving means.



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Patent  
Office

12

Application No: GB 9817732.2  
Claims searched: 1-14

Examiner: Dr. Robert Fender  
Date of search: 29 September 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): E1F: FHK, FHU, FLM

Int Cl (Ed.6): E21B 47/12, 47/14, 47/16, 47/18

Other: Online WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2210087 A (BAKER HUGHES INCORPORATED) see figures 1A & B, in particular sensors 50 and transmitter/receiver coupler half 80, 92	1, 2, 4, 5, 9 & 10
X	EP 0773345 A1 (SCHLUMBERGER TECHNOLOGY) see figure 2, in particular sensor 16 and downhole unit 24	1, 2, 9 & 10
X	US 5721538 (BAKER HUGHES INCORPORATED) see figures 1 & 2 and column 5 lines 1-17	1, 2, 4, 5, 9, 10, 12-14
X	US 5531270 (ATLANTIC RICHFIELD COMPANY) see figures 1 & 4 and column 4 lines 24-60	1-5, 9 & 10

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	B	Patent document published on or after, but with priority date earlier than, the filing date of this application.



Application No: GB 9817732.2  
Claims searched: 15 & 16

Examiner: Dr. Robert Fender  
Date of search: 4 August 1999

**Patents Act 1977**  
**Further Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): E1F FHK, FHU, FLM

Int Cl (Ed.6): E21B 47/12, 47/14, 47/16, 47/18

Other: Online: WPI, EPDOC

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	US 5721538 (Baker Hughes Incorporated) see figures 1 & 2 and column 5 lines 1-17	-
A	US 5706896 (Baker Hughes Incorporated)	-

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
Y Document indicating lack of inventive step if combined with one or more other documents of same category.	P Document published on or after the declared priority date but before the filing date of this invention.
& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.